SANDIA REPORT

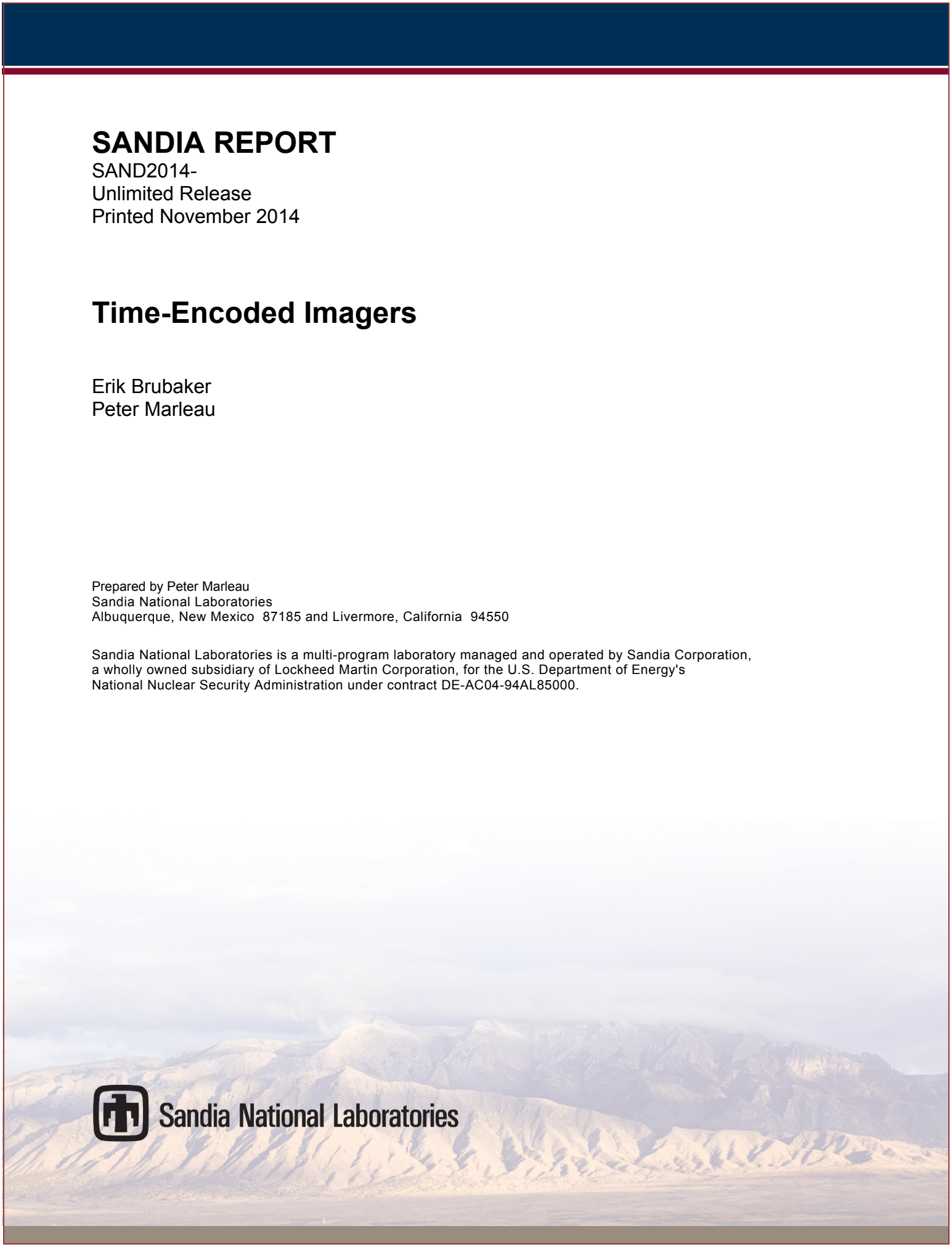
SAND2014-
Unlimited Release
Printed November 2014

Time-Encoded Imagers

Erik Brubaker
Peter Marleau

Prepared by Peter Marleau
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represent that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

SAND2014-19811
Unlimited Release
November 2014

Time-Encoded Imagers

Peter Marleau
Radiation and Nuclear Detection Systems
Sandia National Laboratories
7011 East Avenue
Livermore, CA 94550-MS9406

Abstract

This report provides a short overview of the DNN R&D funded project, Time-Encoded Imagers. The project began in FY11 and concluded in FY14. The Project Description below provides the overall motivation and objectives for the project as well as a summary of programmatic direction. It is followed by a short description of each task and the resulting deliverables.

CONTENTS

Project Description 6
Task 1. Modeling and lab tests to refine standoff imaging system design 6
Task 2. Engineer and build a full-scale time-encoded standoff detector. 7
Task 3. Develop a design concept for two-dimensional time-encoded imaging 7
Task 4. Testing and characterization of standoff detector 7
Task 5: Engineer and build a two-dimensional time-encoded detector system 7
Task 6: Laboratory tests of demonstration detector 8
Task 7: Field test of demonstration detector 8
Task 8: Concept development and modeling of a HPGe-based time-encoded detector 8
Distribution 10

INTRODUCTION

This report provides a short overview of the DNN R&D funded project, Time-Encoded Imagers. The project began in June FY11 and concluded in FY14. The Project Description below provides the overall motivation and objectives for the project. It is followed by a short description of each task and the resulting deliverables.

PROJECT DESCRIPTION

This project sought to demonstrate the advantages of time-encoded imaging for solving outstanding problems in SNM detection. By designing, building, and testing a demonstration time-encoding detector system, we have advanced the understanding of this technique and demonstrated what may be a transformative tool for SNM detection.

To date, all other existing imaging methods require multiple interactions, leading to an intrinsically low efficiency, or spatial modulation of the signal, which requires spatial resolution of the sensitive detector and often leads to a complicated and expensive design with high systematic uncertainties. In contrast, a single detector using a time-modulated collimator can encode directional information in the time distribution of detected events. Before this work time modulation as a means of directional discrimination, or imaging, was an unexplored method for both gamma rays and, especially, high energy neutrons.

We have established feasibility in several proof-of-concept experiments and demonstrations. We foresee two transformative advantages of time-encoded imaging. One is that a new design space is opened for effective and low-cost directional detection. Time-encoding systems can have a low channel count, reducing cost and increasing robustness by simplifying system integration and calibration. They have intrinsically high efficiency, since only a single particle interaction is required. And they are scalable to the large detector size (1000s of cm^2 effective area) needed for large standoff applications. The second advantage is that, with time encoding, the angular resolution of the image reconstruction depends primarily on the collimator design. It is effectively decoupled from the method used for particle detection. Thus in a time-encoding imager both angular resolution and detector performance (e.g. energy resolution) can be independently optimized.

TASK 1. MODELING AND LAB TESTS TO REFINE STANDOFF IMAGING SYSTEM DESIGN

The focus of this task was to refine the one-dimensional standoff detector design. A proof of feasibility prototype imaging system was already developed in a previous LDRD so the primary focus was on improving pulse shape discrimination by better light collection efficiency and data acquisition hardware. This was accomplished in several iterations in which different detector concepts were designed, constructed, and studied in the laboratory. The results of this study are reported in “SL11-TimeImanger-PD2Je Annual Report”, “Marleau NSS2011 TEI ConferenceProceedings.pdf”, “Marleau TEI NSS2011.pptx”.

TASK 2. ENGINEER AND BUILD A FULL-SCALE TIME-ENCODED STANDOFF DETECTOR.

In this task, the results of the studies outlined in task 1 were evaluated and an engineering design for a full-scale time-encoded stand-off detector was finalized. A panel of independent experts was assembled to participate in a design review meeting and their recommendations were incorporated. The system was then fabricated and assembled. The design review slides, panel recommendations, and final system design are reported in "Time-Encoded Imaging Standoff Detector Design Review Report", "Time Encoded Imaging 1D Standoff Detector Design Review Slides", "Time Encoded Imaging 1D Standoff Detector Design Review Updates"

TASK 3. DEVELOP A DESIGN CONCEPT FOR TWO-DIMENSIONAL TIME-ENCODED IMAGING

The focus of this task was to explore different design concepts for a two-dimensional time encoded imaging system. Because much of the preliminary design work for the one-dimensional stand-off system was accomplished with a small LDRD before this project turned on, we were able to add this task with permission from DNN R&D. Several design concepts were investigated using a combination of calculation, modeling, and Monte Carlo simulation. Concepts were evaluated based on their ability to reconstruct high resolution images with a minimum of artifact. The results of the study and a conceptual design for the two-dimensional imaging system are presented in "2013-01-08—TEI2D report(2).pdf" and "2013-04-09—WMS2013—TEI poster.pptx"

TASK 4. TESTING AND CHARACTERIZATION OF STANDOFF DETECTOR

The focus of this task was to test and characterize the performance of the one-dimensional stand-off detector system in the laboratory and field tests. PSD, energy resolution, and detection efficiency were studied as a function of interaction location within the detectors. The system was then tested in field tests in which a neutron source was detected at 100 meter stand-off. Results of these tests are reported in "TEI1D DetectorPerformance Report.docx", "WMS 2014 Poster" [SL11-TimeImager-PD2Jc WMS2014 poster.pptx], "2013Aug01 SL11-TimeImager-PD2Je Deliverable.docx", "SPIE 8852-2 ErikBrubaker.pptx", and "2013 SPIE proceedings.pdf".

TASK 5: ENGINEER AND BUILD A TWO-DIMENSIONAL TIME-ENCODED DETECTOR SYSTEM

In this task, a two-dimensional imaging system was designed based on the lead imaging concept identified in task 3. An engineering design was finalized based on input from a design review panel. That system was fabricated, assembled, and integrated. Design review presentations, recommendations, and final system design are reported in "2D Design Review Presentation" [2013-02-12 TEI2D Design Review.pptx], "2013-03-31—TEI2D Design Review—Feedback.docx", and "2013-01-08—TEI2D report(2).pdf".

TASK 6: LABORATORY TESTS OF DEMONSTRATION DETECTOR

In this task, the two-dimensional imaging system was tested and characterized in the laboratory. Imaging performance for single and multiple point sources were investigated and compared to

coded aperture imaging detectors. Results from these laboratory studies are reported along with results from task 7 in "TEI2D LabStudies Report.docx".

TASK 7: FIELD TEST OF DEMONSTRATION DETECTOR

The focus of this task was to test and characterize the performance of the two-dimensional imaging system to image extended distributions of material. Results from these tests are reported along with results from task 6 in "TEI2D LabStudies Report.docx".

TASK 8: CONCEPT DEVELOPMENT AND MODELING OF A HPGE-BASED TIME-ENCODED DETECTOR

In this unfunded task we proposed to develop a concept for a HPGE-based time-encoded imaging system and investigate its sensitivity in low signal-to-background scenarios. The potential of combining high-resolution spectroscopy and directional information was to be explored.

DISTRIBUTION

1	MS9406	Erik Brubaker	08127
1	MS9406	Peter Marleau	08127
1	MS9406	Craig R. Tewell	08127
1	MS0899	Technical Library	9536 (electronic copy)

Sandia National Laboratories